THE WEATHER AND CIRCULATION OF DECEMBER 1965

Including a Discussion of the Record Dry Year in the Northeast

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1. MEAN CIRCULATION

The upper-level circulation in the Northern Hemisphere during December was one of fast westerlies over the oceans and moderately low index over the continents as can be seen from figures 1, 2, and 3. Over the Pacific the strong westerlies were associated with an extremely long wavelength from the Asiatic coastal trough to the trough along the west coast of North America. The intense trough along the coast of Asia was accompanied by an extensive mass of cold air. This, together with persistent warm air over middle and low latitudes of the Pacific, provided a zone of strong thermal contrast from which developing storms derived energy as they swept northeastward from the coast of Asia to the northern Gulf of Alaska. The inland location of middle-latitude portions of the Asiatic coastal trough was rather unusual this December. In fact this month's trough location was west of any December trough in that region during a recent 14-yr. period studied by Stark [1]. Above normal heights south of Japan represent a circulation anomaly which has persisted since mid-October and which appears related to the weakness of the eastern Asia upper ridge (figs. 1 and 2).

The low-latitude portion of the eastern Pacific trough has had a remarkable long-term continuity, having traversed the Pacific during the fall months [2] with progression continuing through December. Over North America, the pattern of height anomalies is suggestive of blocking, in view of the observed diminution of zonal westerlies. Possibly this represents the remnants of the strong Greenland block of November [3] although continuity in this instance is by no means clear. With progression of the Pacific coast trough and increasing heights over the continent, the Atlantic coast trough moved eastward during December to a position well off the coast (fig. 1).

As blocking in the Atlantic relaxed during December the westerlies markedly increased in that sector. This was accompanied by an increasing wavelength between the western Atlantic trough and the trough to its east as the latter progressed from the coast of Europe to the central Mediterranean and eastern Europe. Weakening of blocking also permitted a return to a more undulating circulation pattern over Europe and Asia from the relatively flat westerly flow of the previous month [3].

2. TEMPERATURE

Over most of the United States the warm temperatures of November [3] continued into December (fig. 4). To a large extent this was due to the weakness of the western ridge (figs. 1–2) implying a dearth of polar outbreaks east of the Rockies in the United States. Highest temperatures relative to normal were found in the Plains States and Mississippi Valley where the above-mentioned effect was coupled with above normal heights and anomalous wind components from the south.

An exception to the warm regime was the Far West where the deep trough along the coast, coupled with a strong ridge from Hawaii to the Aleutians, dropped temperatures below normal. In Alaska below normal heights and stronger-than-normal northwesterly anomalous flow resulted in another relatively cold region.

3. PRECIPITATION

The deep negatively tilted trough off the west coast and the associated southward displacement of the westerlies (figs. 1, 2, and 3) resulted in a major storm track from southern California eastward through northern Arizona to the eastern slopes of the Rockies and thence northeastward to the Great Lakes. Over most of this path southerly wind components aloft were stronger than normal (fig. 2) and above normal precipitation was observed (fig. 5), except for a typical rain shadow effect immediately east of the Continental Divide. In Arizona, where monthly precipitation exceeded 500 percent of normal in some areas, this was one of the wettest Decembers of record. At Flagstaff 6.63 in. of precipitation exceeded normal by 4.98 in. to establish a December record. Low pressure systems moving into northern portions of the west coast trough along the northern wind speed maximum (fig. 3) brought above normal precipitation to much of the Pacific Northwest while in the intermediate zone between this track and the southern storm track precipitation was substantially lighter (fig. 5).

Along the Gulf Coast heavy precipitation was associated with easterly anomalous wind components aloft, while over much of the East subnormal precipitation prevailed. The latter resulted from seaward displacement of the coastal trough coupled with above normal heights and

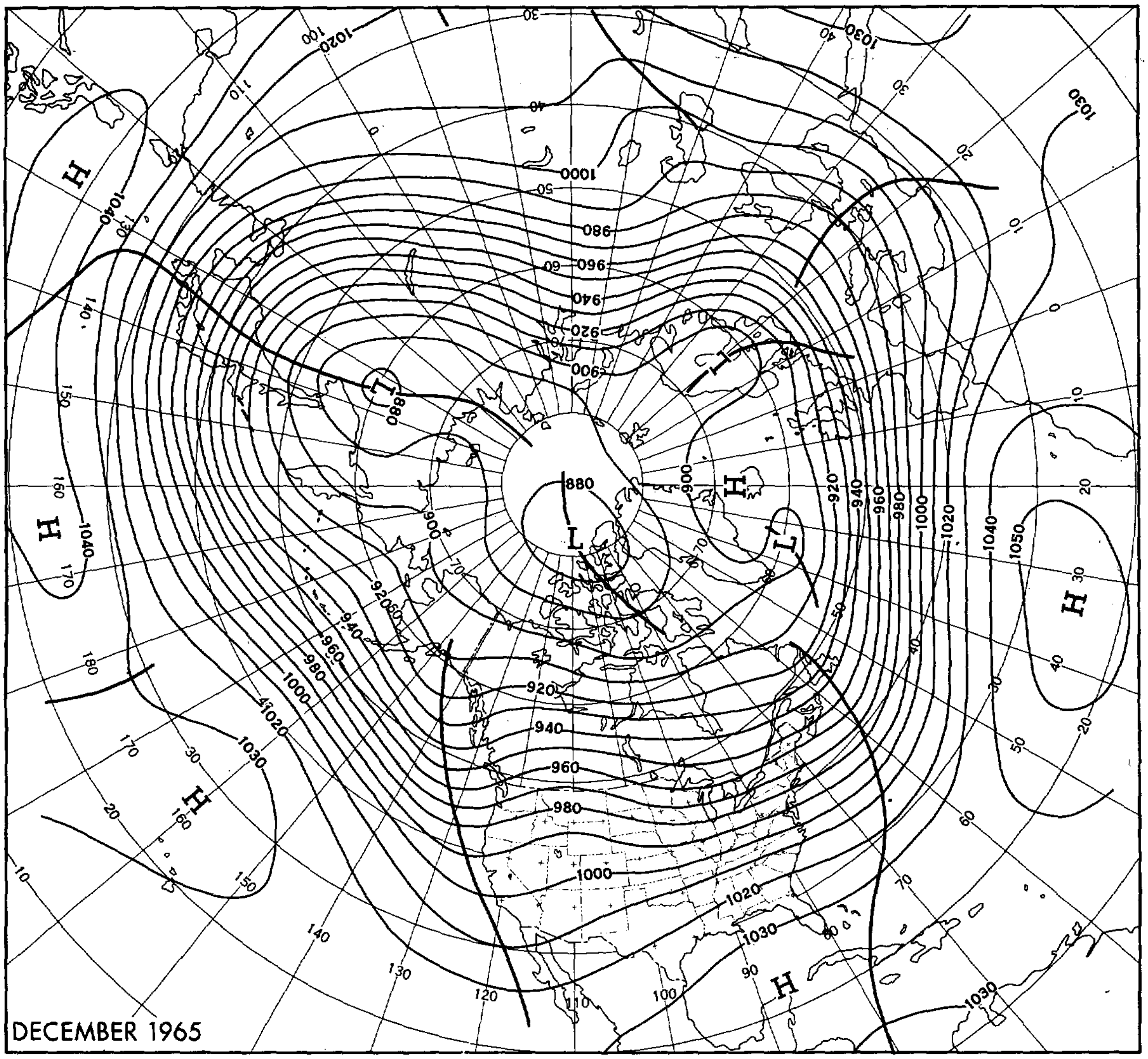

FIGURE 1.—Mean 700-mb. contours (tens of feet), December 1965. Deep trough along west coast brought unusually heavy precipitation to the Southwest.

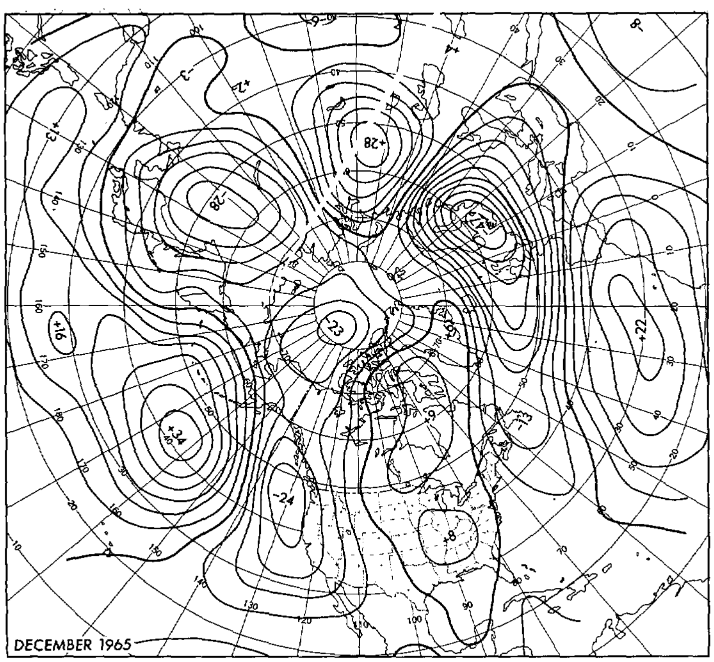

FIGURE 2.—Departure of mean 700-mb. heights from normal (tens of feet), December 1965. Anomalous flow from the north continued drought conditions in the Northeast.

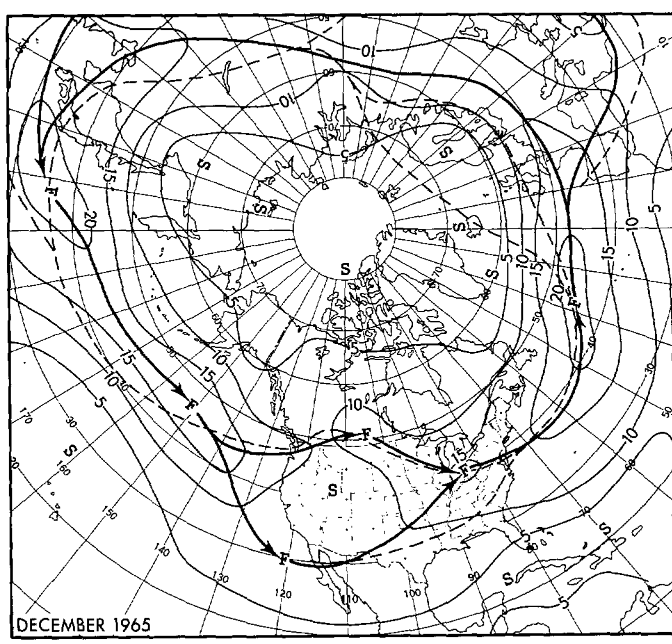

FIGURE 3.—Mean 700-mb. isotachs (meters per second), December 1965. Solid arrows indicate principal axes of maximum wind speed and dashed lines the normal. Wind speed maxima over the oceans were stronger than normal.

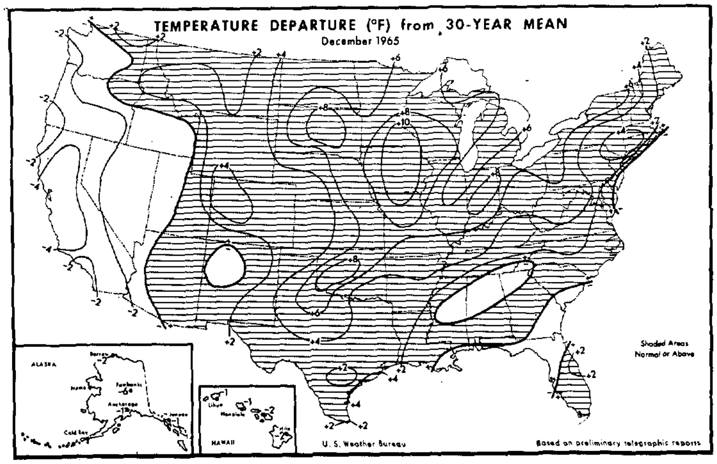

FIGURE 4.—Surface temperature departure from normal (°F.), December 1965 (from [4]).

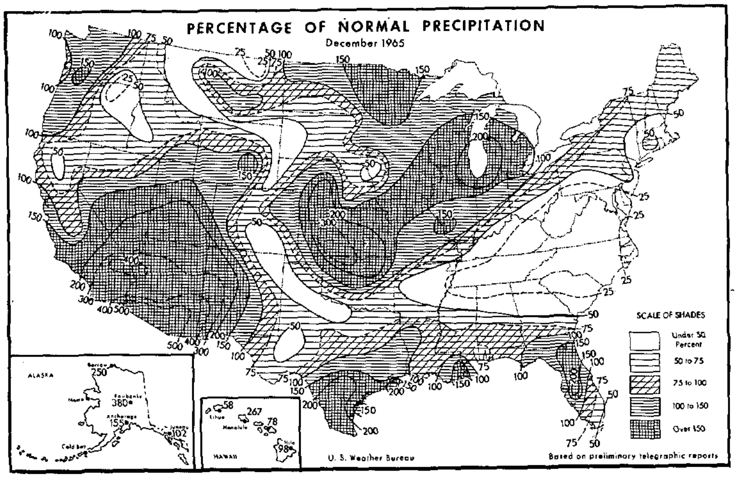

FIGURE 5.—Percentage of normal precipitation, December 1965 (from [4]).

ridge conditions over the continent. One of the driest Decembers of record was reported from Kentucky and Tennessee eastward to the coast with new December precipitation lows established at Charlotte, N.C. (0.43 in.) and Greenville-Spartanburg, S.C. (0.37 in.). Over the northeastern drought area precipitation continued deficient in December, ranging from 1 to 2 in.

In Alaska above normal precipitation was related to a well developed Arctic upper Low and a storm track through northern Alaska.

4. VARIABILITY WITHIN THE MONTH

Weekly distributions of temperature and precipitation during the month, accompanied by appropriate 5-day mean maps, are shown in figures 6 through 10.

Review of the large-scale circulation evolution in December reveals an interesting example of the downstream dispersion of energy during the last half of the month. Deepening off the coast of Asia during December 14–18 (fig. 8A) was followed by strong ridging into the Bering

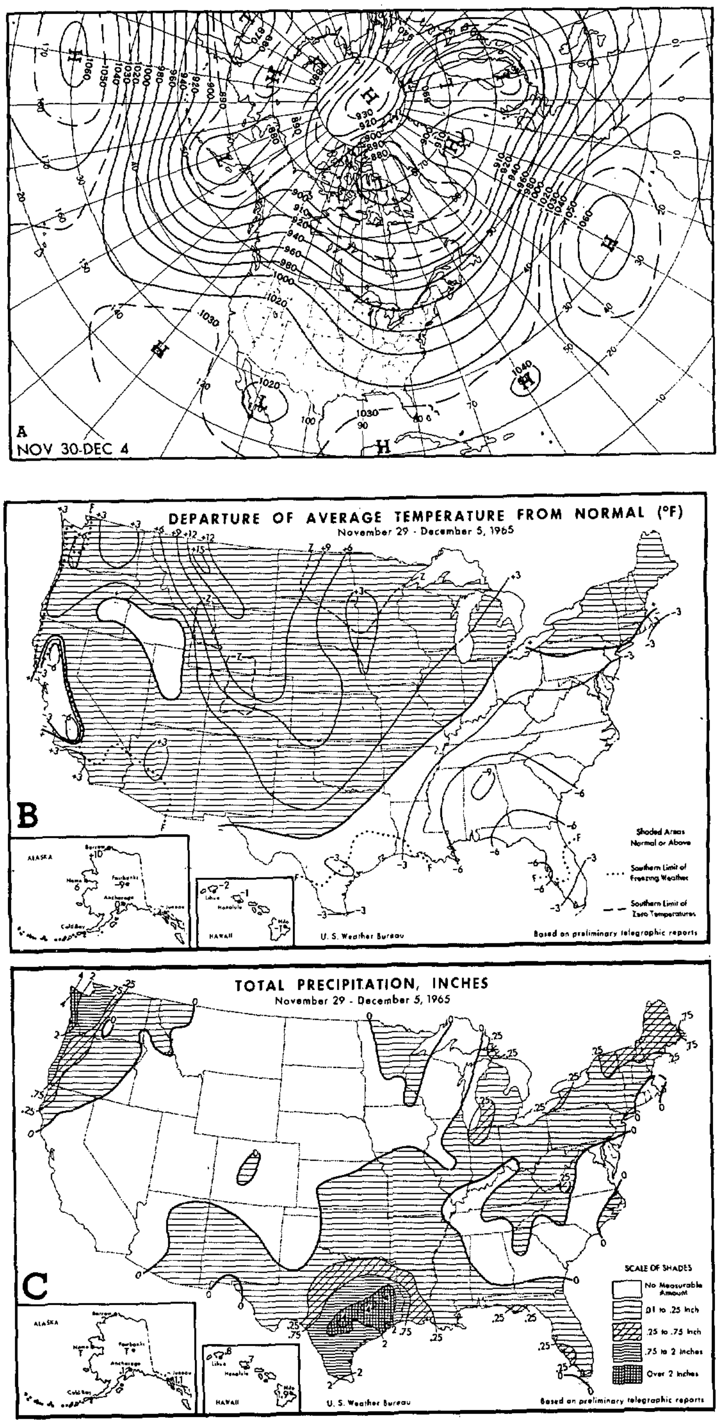

FIGURE 6.—Week of November 29–December 5, 1965: (A) 700-mb. contours (tens of feet), November 30–December 4; (B) surface temperature departure from normal (°F.); (C) total precipitation (in.). (B) and (C) from [4].

Sea region and deepening in the Gulf of Alaska the following week (fig. 9A). By the end of the month (fig. 10A) amplification of the eastern United States ridge was well under way.

With progression of wave features early in the month, cold air in the East during the first week (fig. 6B) was rapidly replaced by above normal temperatures (fig. 7B)

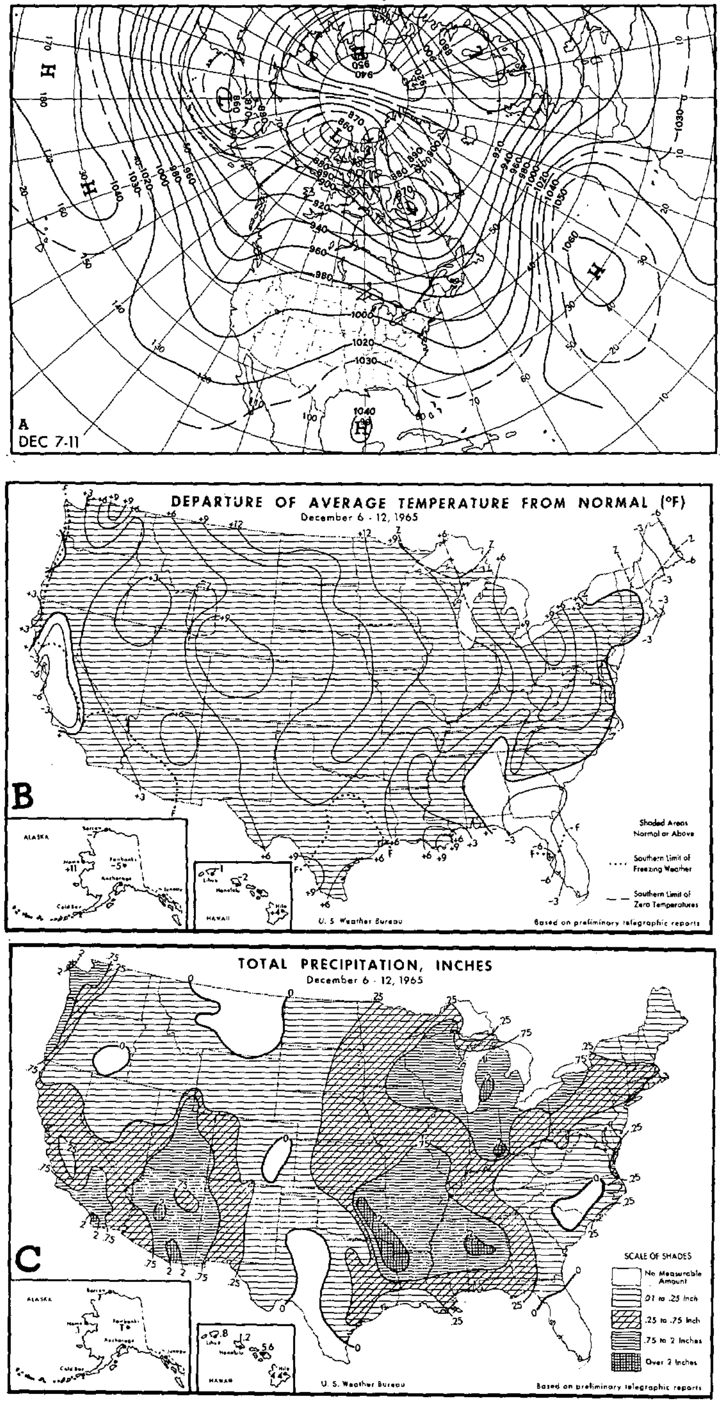

FIGURE 7.—Week of December 6–12, 1965: (A) 700-mb. contours (tens of feet), December 7–11; (B) and (C) same as figure 6.

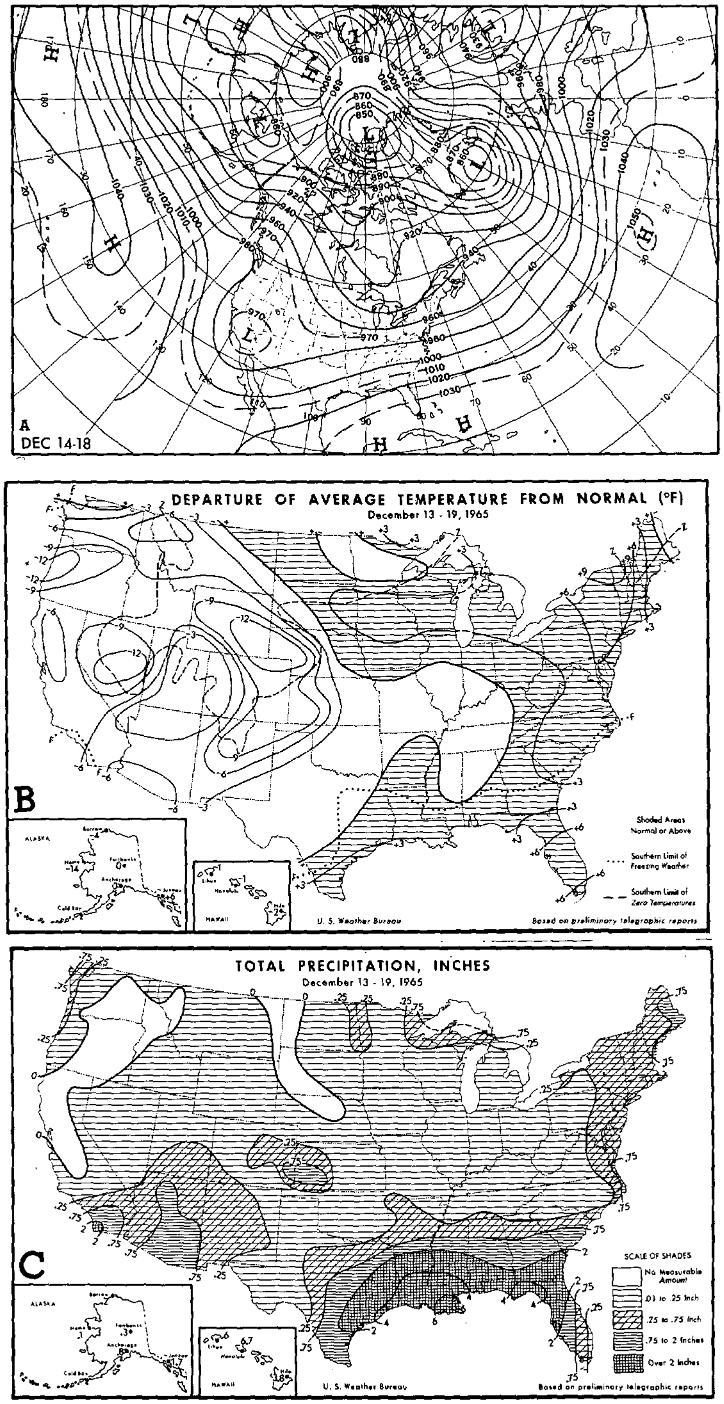

FIGURE 8.—Week of December 13–19, 1965: (A) 700-mb. contours (tens of feet), December 14–18; (B) and (C) same as figure 6.

which persisted during most of the remainder of the month. Cold air was thrust across the western half of the Nation in connection with the shearing trough of December 14–18 (figs. 8A and B), pushing across the South during the following week (figs. 9A and B) as a blocking ridge developed over northeastern Canada. By the final week of the month (figs. 10A and B) a deep Gulf of Alaska Low together with ridging in the East, had returned above normal temperatures to most areas.

Approach of the mean upper trough from the west reinstituted a wet regime in the Southwest during the second week (figs. 7A and C) which continued for the rest of the month (figs. 8C, 9C, and 10C) and resulted in flooding in Arizona and parts of southern California during the last half of the month. On the 10th and again on the 22d, storms moved out of the Southwest and deepened strongly in the zone of thermal contrast separating cold western air from warmer air to the east. These storms

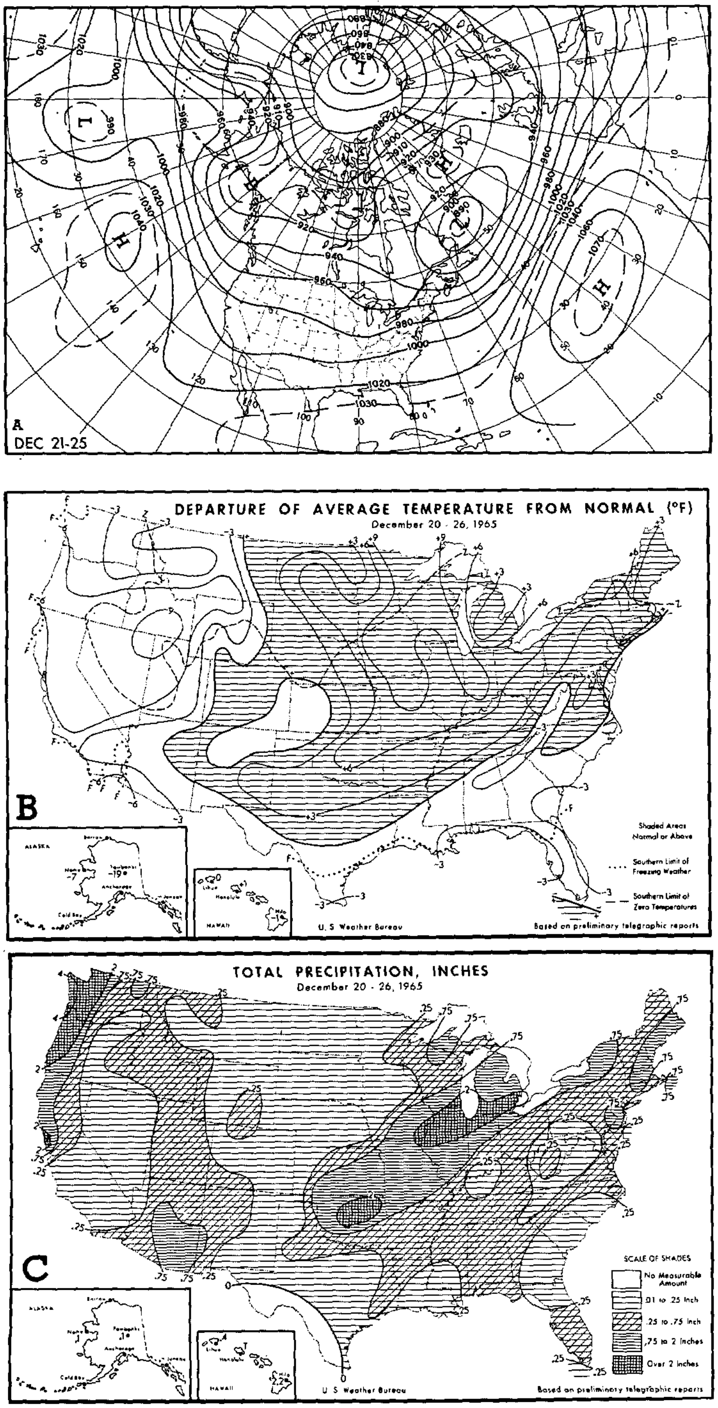

FIGURE 9.—Week of December 20–26, 1965: (A) 700-mb. contours (tens of feet), December 21–25; (B) and (C) same as figure 6.

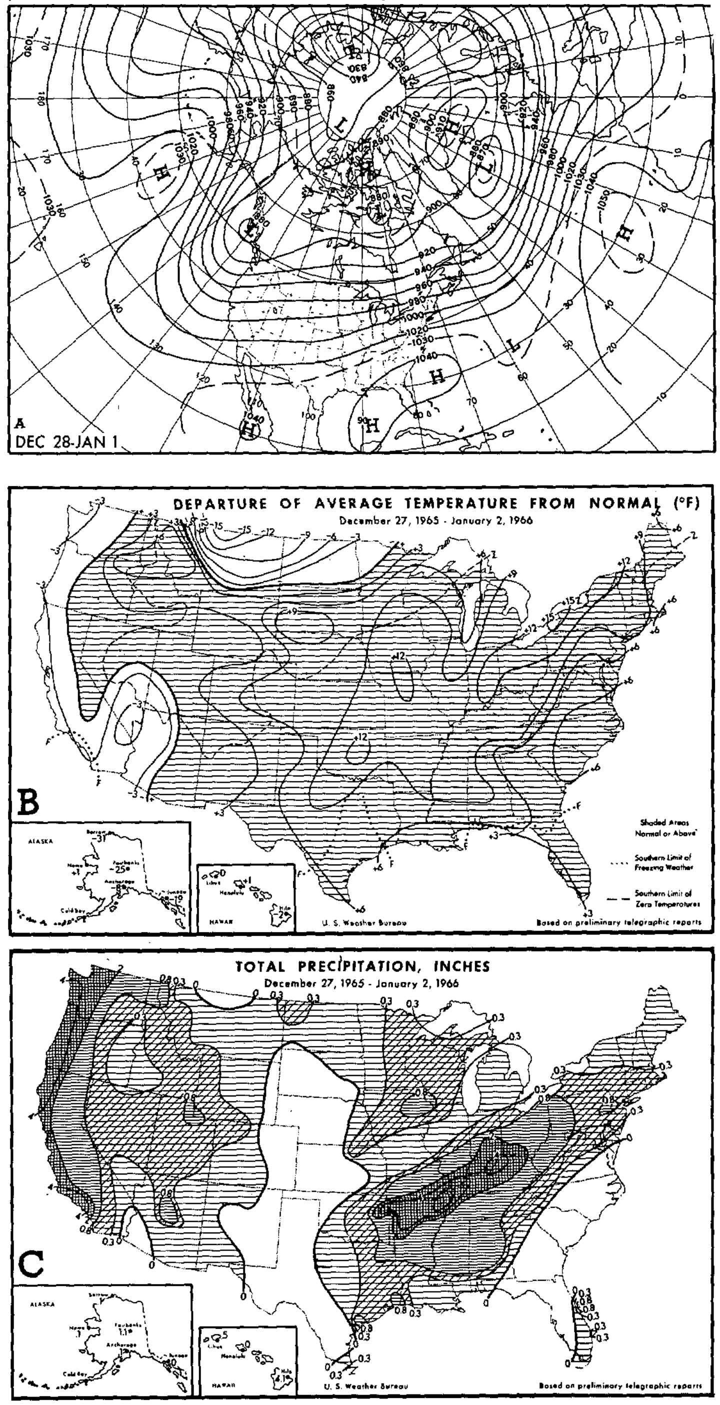

FIGURE 10.—Week of December 27, 1965–January 2, 1966: (A) 700-mb. contours (tens of feet), December 28–January 1; (B) and (C) same as figure 6.

provided major contributions to the monthly precipitation from the Southwest northeastward through the Great Lakes Region (figs. 7C and 9C). Rainfall along the Gulf Coast was associated with a succession of weak waves traveling along slow-moving fronts in the Gulf during weeks when the westerlies were south of normal (mainly, figs. 6 and 8). In the Pacific Northwest precipitation was well distributed throughout the month, but was most intense during the final 10 days when vigorous cyclogenesis took place in the Gulf of Alaska (figs. 9 and 10).

5. RECORD DRY YEAR IN NORTHEAST

The past year was the driest of record at many locations in the northeastern United States (including those listed in table 1). The geographical extent of the region of annual precipitation deficiency is shown in terms of percent

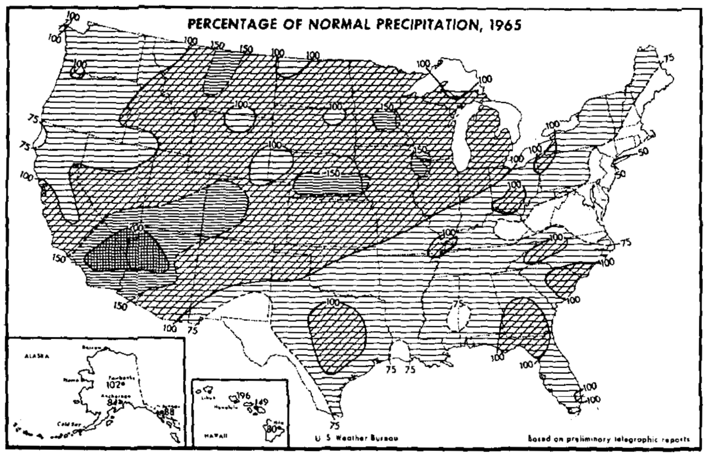

FIGURE 11.—Percentage of normal precipitation, 1965 (from [4]).

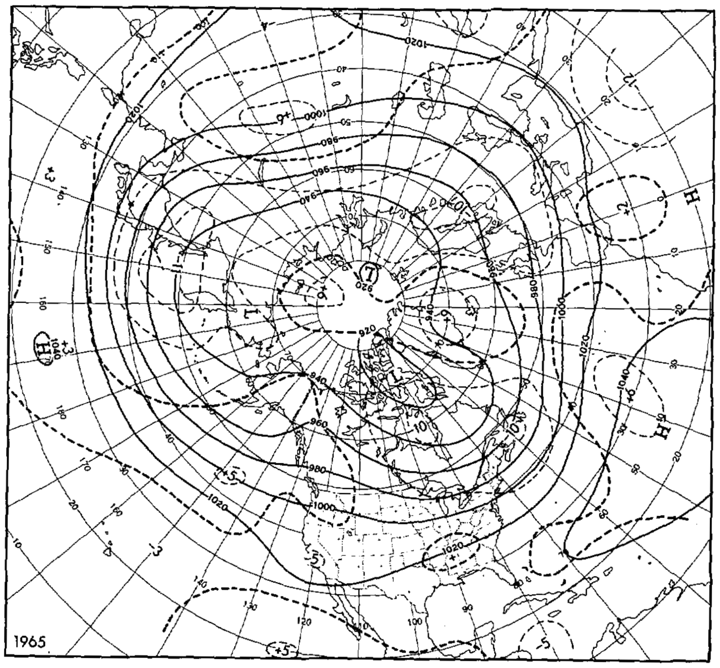

FIGURE 12.—Mean 700-mb. height and departure from normal (both in tens of feet) for 1965.

of normal precipitation in figure 11. Reference to the annual mean 700-mb. circulation and its departure from normal, shown in figure 12, provides insight into the large-scale circulation anomalies which were associated with this extreme precipitation deficiency. It is apparent that a major factor in producing the drought was the persistent recurrence of a deeper-than-normal trough off the east coast of the United States. Implicit in this trough location is a seaward displacement of the coastal storm track and the consequent reduction in the contribution of this important storm type to precipitation in the Northeast. Expressed another way, the eastward trough displacement resulted in the persistent recurrence of stronger-than-normal upper wind components from the northwest bringing subsiding, rain-inhibiting air masses over the drought area.

Figure 12 places the drought-producing circulation anomaly in the eastern United States in hemispheric perspective. The east coast trough was a part of an amplified wave pattern which circled the globe producing remarkably similar circulation anomalies over the United States and eastern Asia. The relatively deep low-latitude trough near California (fig. 12) was associated with a more active than normal storm track from the Southwest northeastward over the Great Lakes bringing above normal precipitation to these areas (fig. 11). Thus, while the Northeast was experiencing a severe drought, Sault Ste. Marie, Mich., Waterloo, Iowa, Rockford, Ill., St. Cloud, Minn., and Flagstaff, Ariz., were accumulating record-high annual precipitation totals.

TABLE 1.—*Cities reporting lowest annual precipitation of record in 1965*

City	Precipitation (in.)	
	Total	Departure From Normal
Boston, Mass.	23.71	−19.06
Concord, N.H.	24.17	−14.63
Wilmington, Del.	24.90	−19.66
Nantucket, Mass.	25.31	−18.35
Providence, R.I.	25.44	−16.69
Norfolk, Va.	26.64	−18.30
New Haven, Conn.	27.66	−18.36
Hartford, Conn.	29.45	−13.47

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(*Continued from page 140*)

the cloud and shower belts in both tropical and higher latitudes. In 1958 I suggested that "this relationship may provide a basis for establishing physical homologies in such diverse phenomena as the middle latitude squall lines and the hurricane spiral bands . . ." (Carson [1]), and I have subsequently published another paper [2] which develops this thesis further and presents additional evidence in support thereof from radar and satellite data. I can supply a copy of this to anyone who requests it as long as the supply lasts.

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4. J. W. Sandström, "On the Motion of Fluids," *Annalen der Hydrographie und Maritimen Meteorologie*, vol. 37, June 1909.
5. [Staff, National Environmental Satellite Center], "Picture of the Month," *Monthly Weather Review*, vol. 93, No. 11, November 1965, p. 662.

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Reply

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The purpose of the "Picture of the Month," explained when this series was started [2], is to present stimulating satellite pictures. We are happy this one has stimulated Mr. Carson and we hope that this exchange of correspondence will proliferate the interest.

We concur completely with the first two paragraphs of Mr. Carson's letter: More attention and thought should be devoted to this type of situation. We do not entirely concur with Mr. Carson's summary of the picture evidence. The cloud band spiraling in from the east has quite a different character than the band spiraling in from across the bottom of the picture. The density and brightness of the former, contrasted to the broken appearance of the latter, implies that the amount of cloudiness, intensity of convection, and degree of multi-level cloudiness is somewhat different in the two bands.

In a limited sense the two bands may indeed be "homologous" in that they both represent elongated curved bands of convergence and the resulting upward motion. While such negative asymptotes have the same *kinematic* character, the *origin* might be different. In one case, a baroclinic (frontal) zone produces the uplift, in the other case an unidentified dynamic mechanism.

In our terminology we follow the practice of the National Meteorological Center, which defines a front as a sloping discontinuity in the density gradient such that the thermal wind shear in the 1000–500-mb. layer must exceed 25 kt. It has been widely observed that fronts defined in terms of such baroclinicity do not explain all of the significant weather and cloud bands. Satellite pictures are visible proof of this point which Mr. Carson has discussed.

The brief description necessitated by the format of this monthly feature prevents an explanation of the basis for some of the conclusions. This brevity has apparently led Mr. Carson to misinterpretation. The cloud band spiraling into the center from the east does ". . . correspond[s] to the occluded front." This does not mean that the surface map must show a spiral purple line in order to agree with the picture. Rather, the solid cloud band corresponds to the trough of saturated warm air forced aloft by the occlusion as it spirals about the center. Examination of the available analyses justifies this interpretation even though the surface front terminates near the northernmost portion of the cloud spiral.

The *suggestion* that the cloud band along the bottom of the picture might be associated with a jet was made because similar appearing sharp-edged bands have sometimes been observed marking the southern edge of the polar jet.* These bands, when associated with jets, are composed of cirrus clouds at least along the least-curved portion. The jet stream must, of course, depart at some point from the spiral pattern because, in agreement with Mr. Carson's observations, we have never seen a spiral jet. In this particular case we have reexamined the available observations. It appears that this band was probably not composed of jet-associated cirrus; the geostrophic winds were apparently too weak, and in the broken eastern portion the clouds were mostly low-level cumuliform.

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2. S. Fred Singer, "Introduction to Picture of the Month Series," *Monthly Weather Review*, vol. 91, No. 1, Jan. 1963, p. 1.
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*This subject was discussed by Oliver, Anderson and Ferguson [1] and is further investigated in a paper by Whitney, Timchalk, and Gray [3] in the present issue.

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